DOE/NV/26383-LTR2008-04

Letter Report

Yucca Mountain Environmental Monitoring Systems Initiative

Air Quality Scoping Study for Tonopah Airport, Nye County, Nevada

prepared by

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submitted to

Nevada Site Office
National Nuclear Security Administration
U.S. Department of Energy
Las Vegas, Nevada

August 2008

The work upon which this report is based was supported by the U.S. Department of Energy under Contract #DE-AC52-06NA26383.

Erata Sheet

Yucca Mountain Environmental Monitoring Systems Initiative
Air Quality Scoping Study for Caliente, Lincoln County, Nevada

Page 3, 4th line from the bottom, date should read December 5, 2006
Page 21, caption should read: Figure 22. Wind direction and speed (mph) at Caliente.
Page 24, last para, last sentence should read: This may be explained by water-bound clay and organic particles.

Yucca Mountain Environmental Monitoring Systems Initiative
Air Quality Scoping Study for Crater Flat, Nye County, Nevada

Page 6, Table 3, line 12, should be Ca^{2+}
Page 18, caption should read: Figure 18. Wind direction and speed (mph) at Crater Flat.
Page 21, first paragraph line 6, date should be July 29, 2007

Yucca Mountain Environmental Monitoring Systems Initiative
Air Quality Scoping Study for Pahranagat National Wildlife Refuge, Lincoln County, Nevada

Page 3, third line from bottom, date should read February 17, 2007
Page 6, Table 3, line 12, should be Ca^{2+}
Page 21, caption should read: Figure 22. Wind direction and speed (mph) at Pahranagat NWR.
Page 22, line 9 should read: southeasterly and northerly winds (Figure 25 and Figure 26).

Yucca Mountain Environmental Monitoring Systems Initiative
Air Quality Scoping Study for Tonopah Airport, Nye County, Nevada

Page 10, 3rd line from the bottom, date should read August 29, 2007
Page 7, Table 3, line 5, should be Ca^{2+}
Page 21, caption should read: Figure 22. Wind direction and speed (mph) at Tonopah Airport.

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INTRODUCTION

The Desert Research Institute (DRI) is performing a scoping study as part of the U.S. Department of Energy's Yucca Mountain Environmental Monitoring Systems Initiative (EMSI). The main objective is to obtain baseline air quality information for Yucca Mountain and an area surrounding the Nevada Test Site (NTS).

Air quality and meteorological monitoring and sampling equipment housed in a mobile trailer (shelter) is collecting data at eight sites outside the NTS, including Ash Meadows National Wildlife Refuge (NWR), Tonopah Airport, Beatty, Rachel, Caliente, Pahranagat NWR, Crater Flat, and the Tonopah Airport, and at four sites on the NTS (Engelbrecht *et al*., 2007a-d). The trailer is stationed at any one site for approximately eight weeks at a time.

This letter report provides a summary of air quality and meteorological data, on completion of the site's sampling program.

SITE LOCATION AND CHARACTERISTICS

Tonopah Airport is located 7 miles east of the town of Tonopah, Nevada, along U.S Route 6. The population of Tonopah is approximately 2,627 and covers a total area of 16.2 square miles. It is located in the hills of the San Antonio range at about 6,030 ft elevation. The airport is about 286 miles north of Las Vegas and about 95 miles north of the proposed Yucca Mountain repository (Figure 1).

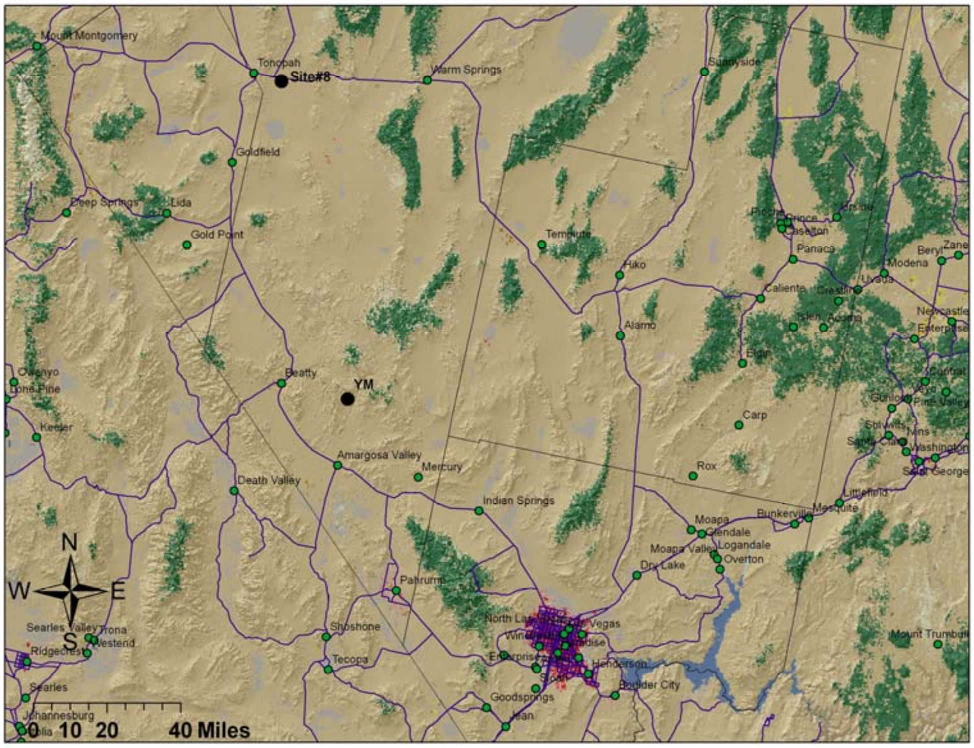

Figure 1. Southern Nevada map showing the location of Site #8 (at Tonopah Airport), Nevada Test Site, and Yucca Mountain. The map background is land use and land cover from the 2001 National Land Cover Database.

The mobile trailer was located adjacent to Tonopah Airport on the south end of the runway about 1.6 miles south of U.S. Route 6. Monitoring of PM_{10}, $PM_{2.5}$, and meteorological conditions was carried out from August 29, 2007, to December 19, 2007.

Table 1. Longitude, latitude, and elevation of the mobile trailer location at Site #8 (Tonopah Airport).

Site	Tonopah Airport
Latitude	38° 31' 33"
Longitude	117° 56' 45"

AEROSOL SAMPLING AND MONITORING

Filter Sampling

Sampler Description and Procedures

BGI, Inc., PQ100 and PQ200 Ambient $PM_{2.5}$ Federal Reference Method (FRM) samplers were used to collect 24-h integrated PM_{10} and $PM_{2.5}$ samples. Figure 2 shows the PQ100 and PQ200 in the mobile trailer (left) and the PM_{10} sampling inlets on the top of the trailer (right). Both the PQ100 (Designation No. RFPS-1298-124) and PQ200 (Designation No. RFPS-0498-116) samplers are designed to meet the criteria for collecting 24-h samples of ambient aerosol according to the U.S. National Ambient Air Quality Standards (NAAQS).

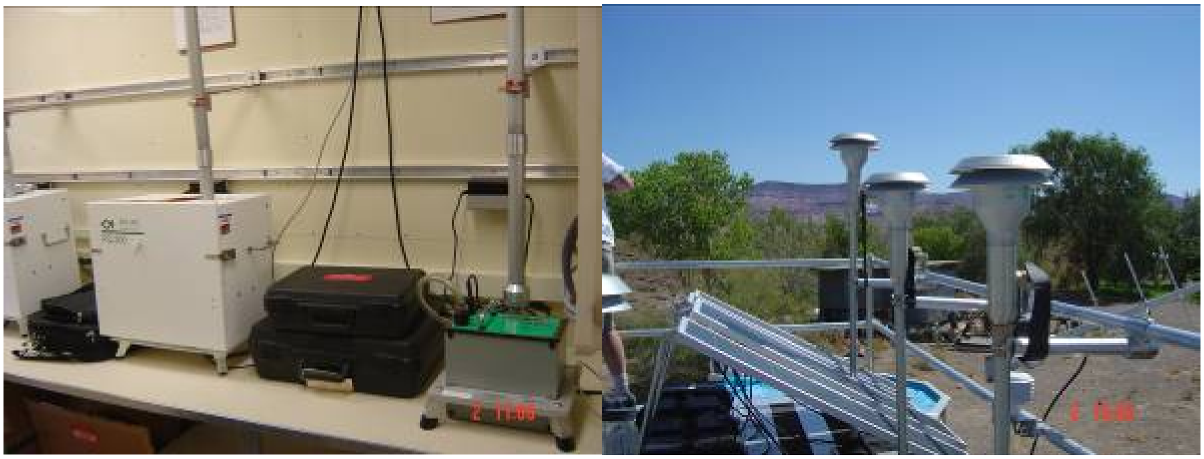

Figure 2. Photographs of PQ100 (green/gray box in left photo), PQ200 (white box in left photo) and their sampling inlets (right photo).

Figure 3 shows a schematic drawing of the samplers. Particles with aerodynamic diameter larger than 10 μm were removed by impaction at the PM_{10} size selective inlet. For the PM_{10} fraction, particles were then collected by a filter located downstream of the size selective inlet. For the collection of $PM_{2.5}$, particles in the range between 2.5 and 10 μm were removed by the Very Sharp Cut Cyclone (VSCC) (U.S. Environmental Protection Agency [EPA] Equivalent Designation No. EQPM-0202-142), then collected on a filter.

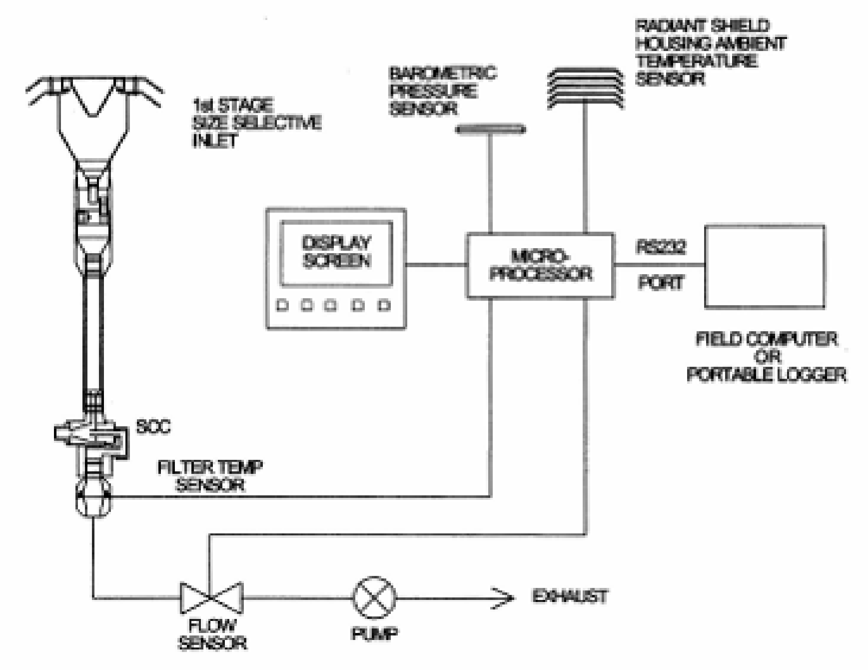

Figure 3. A diagrammatic representation of the BGI $PM_{2.5}$ sampler showing the PM_{10} size selective impactor head as the first stage followed by a $PM_{2.5}$ VSCC. This configuration can be readily modified to a PM_{10} sampler by removal of the VSCC.

For both PQ100 and PQ200, samples were collected at a volumetric flow rate of 16.67 liters/min. The flow rate is controlled to ±2 percent precision with a mass flow controller. The actual ambient temperature and barometric pressure, filter temperature and pressure, and anomalies (if any) were recorded (and controlled) by a microprocessor. The sampler was equipped to operate from an internal 12-volt DC battery. The battery was recharged by a battery charger from 120-volt AC. Alternatively, a 32-watt solar panel with an additional external ballast battery was installed to provide power for periods without electricity. Two sets of PQ100 and PQ200 samplers were installed in the mobile trailer. PM_{10} and $PM_{2.5}$ samples were collected on filters in numbered cassettes, labeled TT (for PM_{10} Teflon), FT (for $PM_{2.5}$ Teflon), TQ (for PM_{10} Quartz), and FQ (for $PM_{2.5}$ Quartz). Each filter cassette was loaded with a pre-weighed 46.2-mm-diameter PTFE (Teflon) membrane filter (Whatman # 7592-004) or 47-mm quartz fiber (Pallflex #2500QAT-UP) filter. The Teflon membrane collected particles for measurement of mass by gravimetric analysis, light absorption by densitometry, and elements by x-ray fluorescence spectrometry. Quartz fiber filters were used for measurement of water-soluble ions by atomic absorption spectrometry, ion chromatography, and automated colorimetry, and also for measurement of carbon species by thermal optical reflectance.

Operation, calibration, and maintenance of PQ100 and PQ200 are described in standard operating procedure (SOP) “BGI PQ100 PM10 and PQ200 PM2.5 REFERENCE SAMPLERS FOR THE YUCCA MOUNTAIN AIR QUALITY PROGRAM.” Flow calibration and leak tests (only for PQ200) were performed on the day of installation (August 29, 2007). The leak check was performed according to the manufacturer’s operational instruction manual only for PQ200; no manufacturer’s procedure exists for the

PQ100. The flow rate was calibrated using a BGI Tri-Cal calibrator. The sampler was then placed in calibration or "run" mode and a one-point calibration verification or one-point flow-rate verification was performed. Aerosol samples were collected on a 1-in-6-day schedule. Audits of the flow and leak tests were done onsite at the beginning and end of the monitoring campaign. Teflon and quartz filters were prepared and assembled in their filter holders in the Desert Research Institute's (DRI) Environmental Analysis Facility (EAF) in Reno and shipped to DRI's facilities in Las Vegas. The filters were kept at -4°C and transported to the field in a cryo-cooler. Exposed filters were also stored at -4°C in Las Vegas. Upon completion of the monitoring period at the site, all filters were shipped to the EAF in Reno.

Gravimetry

Table 2 shows mass concentrations (and uncertainty) of filters collected at the Tonopah Airport. PM_{10} mass concentrations varied from 0.54 µg/m^3 to 19.76 µg/m^3, while $PM_{2.5}$ mass concentrations ranged from 0.21 µg/m^3 to 15.94 µg/m^3. Similar temporal trends were observed for both PM_{10} and $PM_{2.5}$. In all cases, 24-h PM_{10} and $PM_{2.5}$ levels were significantly lower than the daily and annual NAAQS as recently revised by EPA (24-h PM_{10}: 150 µg/m^3, 24-h $PM_{2.5}$: 35 µg/m^3; Annual $PM_{2.5}$: 15 µg/m^3) (Figure 4). Fine particles ($PM_{2.5}$) accounted for approximately two-thirds of PM_{10} ($PM_{2.5}/PM_{10}$ ratio of 0.64) (Figure 5). This value was comparable to that observed for traffic sites in urban areas probably due to the contribution of traffic emissions from U.S. Highway 6 and the nearby airport. However, note that PM_{10} and $PM_{2.5}$ concentration levels are quite low, which indicates the moderate-to-low contribution of windblown dust sources at Tonopah Airport for the monitoring period.

Table 2. Collection day, filter number, mass, and uncertainty determined by gravimetric analysis and associated flags of samples at Site #8 (Tonopah Airport).

Date	No	Type	Mass (µg/m^3)	Uncertainty (µg/m^3)	Flags
9/03/2007	106	PM_{10}	11.7304	0.4877	
		$PM_{2.5}$	5.1165	0.4397	
9/09/2007	107	PM_{10}	10.6073	0.4773	
		$PM_{2.5}$	6.5308	0.4471	
9/15/2007	108	PM_{10}	4.4925	0.4369	
		$PM_{2.5}$	3.4942	0.4333	
9/21/2007	109	PM_{10}	6.4060	0.4464	
		$PM_{2.5}$	2.2888	0.4302	
9/27/2007	110	PM_{10}	7.7787	0.4550	
		$PM_{2.5}$	2.7038	0.4310	
10/03/2007	111	PM_{10}	3.9102	0.4347	
		$PM_{2.5}$	0.2080	0.4276	
10/09/2007	112	PM_{10}	3.6575	0.4335	
		$PM_{2.5}$	1.9975	0.4296	
10/15/2007	113	PM_{10}	3.4942	0.4333	
		$PM_{2.5}$	2.5385	0.4308	
10/21/2007	114	PM_{10}	1.0815	0.4282	
		$PM_{2.5}$	0.5410	0.4279	
10/27/2007	115	PM_{10}	19.5785	0.5822	
		$PM_{2.5}$	15.9384	0.5335	
11/02/2007	117	PM_{10}	-99.0000	-99.0000	B: Field blanks
		$PM_{2.5}$	-99.0000	-99.0000	

Table 2. Collection day, filter number, mass, and uncertainty determined by gravimetric analysis and associated flags of samples at Site #8 (Tonopah Airport) (continued).

Date	No	Type	Mass ($\mu g/m^3$)	Uncertainty ($\mu g/m^3$)	Flags
11/08/2007	116	PM_{10}	4.7837	0.4382	
		$PM_{2.5}$	3.0795	0.4322	
11/14/2007	118	PM_{10}	0.9567	0.4280	
		$PM_{2.5}$	0.4578	0.4279	
11/20/2007	119	PM_{10}	2.0799	0.4296	
		$PM_{2.5}$	1.6646	0.4291	
11/26/2007	120	PM_{10}	1.4559	0.4286	
		$PM_{2.5}$	0.8735	0.4280	
12/02/2007	121	PM_{10}	3.3278	0.4328	
		$PM_{2.5}$	2.1223	0.4299	
12/07/2007	122	PM_{10}	-99.0000	-99.0000	B: Field blanks
		$PM_{2.5}$	-99.0000	-99.0000	
12/08/2007	123	PM_{10}	0.5408	0.4277	
		$PM_{2.5}$	0.4994	0.4279	
12/14/2007	124	PM_{10}	0.7072	0.4278	
		$PM_{2.5}$	0.7903	0.4279	

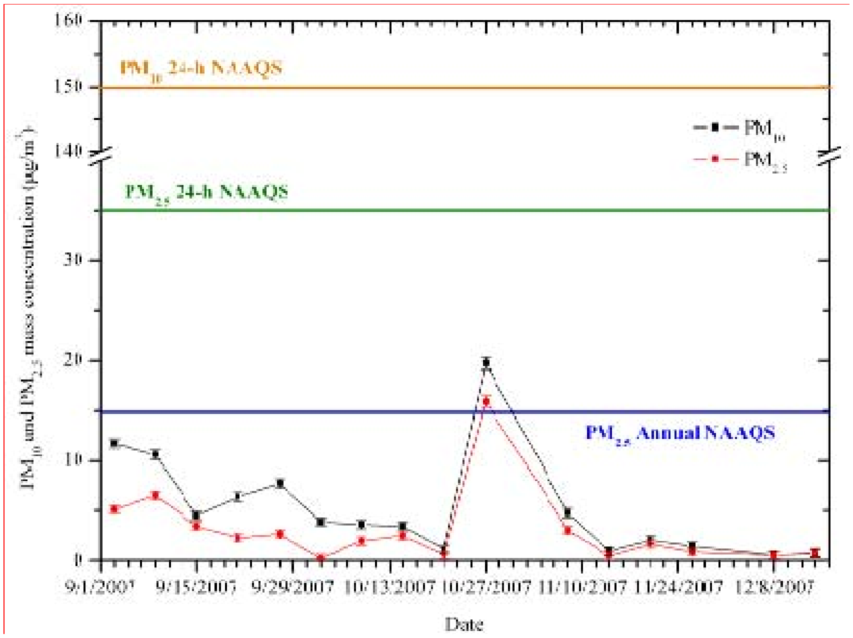

Figure 4. Time series of PM_{10} and $PM_{2.5}$ mass concentrations (± uncertainty) at Site #8 (Tonopah Airport).

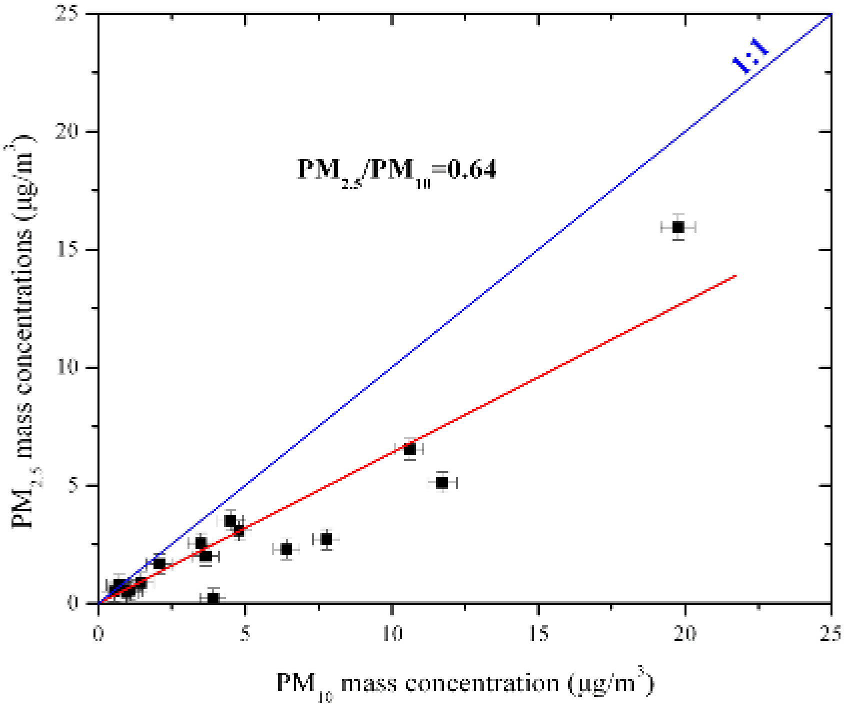

Figure 5. Relationship between mean (± uncertainty) daily $PM_{2.5}$ and PM_{10} at Tonopah Airport.

Chemical Analysis

Table 3 shows the chemical content of PM_{10} and $PM_{2.5}$ samples collected on October 27, 2007, and November 8, 2007. Chemical analysis included elements (from sodium to uranium) with x-ray fluorescence spectrometry (XRF), major anions (sulfate, nitrate, and chloride) by ion chromatography (IC), major cations (sodium, potassium) by atomic absorption (AA), particulate ammonium by automated colorimetry (AC), and elemental and organic carbon by thermal optical reflectance (TOR).

Table 3. Results of the chemical analysis for selected filters from Tonopah Airport. Chemical components with concentration higher than two times the uncertainty are in bold, while those with concentrations lower than two times the uncertainty are in italics. Concentrations are in µg/m^3.

DATE	10/27/2007				11/08/2007			
SIZE	PM_{10}		$PM_{2.5}$		PM_{10}		$PM_{2.5}$	
	Conc.	Uncer.	Conc.	Uncer.	Conc.	Uncer.	Conc.	Uncer.
Mass	**19.5785**	**0.5822**	**15.9384**	**0.5335**	**4.7837**	**0.4382**	**3.0795**	**0.4322**
Chloride, Cl^-	*0.0483*	*0.0297*	*0.0355*	*0.0296*	*0*	*0.0294*	*0.039*	*0.0296*
Nitrate, NO_3^-	**0.5865**	**0.0351**	**0.3493**	**0.0317**	**0.159**	**0.03**	**0.0143**	**0.0295**
Sulfate, SO_4^{2-}	**0.8375**	**0.0346**	**0.7558**	**0.0337**	**1.0836**	**0.0377**	**1.0766**	**0.0376**
Ammonium, NH_4^+	**0.441**	**0.0335**	**0.3799**	**0.0326**	**0.3942**	**0.0328**	**0.3962**	**0.0328**
Sodium, Na^+	*0.055*	*0.0058*	*0.023*	*0.0056*	*0.0146*	*0.0056*	*0.0145*	*0.0056*
Magnesium, Mg^{2+}	**0.0433**	**0.0017**	**0.0064**	**0.0012**	**0.0111**	**0.0012**	**0.0037**	**0.0012**

Table 3. Results of the chemical analysis for selected filters from Tonopah Airport. Chemical components with concentration higher than two times the uncertainty are in bold, while those with concentrations lower than two times the uncertainty are in italics. Concentrations are in µg/m^3 (continued).

DATE	10/27/2007				11/08/2007			
SIZE	PM$_{10}$		PM$_{2.5}$		PM$_{10}$		PM$_{2.5}$	
	Conc.	Uncer.	Conc.	Uncer.	Conc.	Uncer.	Conc.	Uncer.
Potassium, K$^+$	**0.2576**	**0.007**	**0.2133**	**0.0061**	**0.0201**	**0.003**	**0.0163**	**0.003**
Calcium, Ca$_{2+}$	**0.3978**	**0.0181**	**0.0455**	**0.0153**	**0.1609**	**0.0158**	**0.0259**	**0.0153**
OC1	**0.1351**	**0.0564**	**0.3043**	**0.1198**	*0*	*0.0208*	*0.0741*	*0.0355*
OC2	**1.0346**	**0.2432**	**1.2721**	**0.2937**	*0.0789*	*0.0569*	**0.3265**	**0.0976**
OC3	**2.2191**	**0.3449**	**2.2645**	**0.3501**	*0.1629*	*0.1521*	**0.2347**	**0.1558**
OC4	**1.2165**	**0.1358**	**1.245**	**0.1385**	*0.0787*	*0.0523*	**0.1134**	**0.0532**
Pyrolyzed OC-TT	**2.1507**	**0.7331**	**2.0421**	**0.6962**	*0.0612*	*0.0424*	**0.055**	**0.0414**
Pyrolyzed OC-Op	**1.7488**	**0.6216**	**1.5809**	**0.5622**	*0.0399*	*0.0396*	**0**	**0.037**
Total OC	**6.3541**	**0.6036**	**6.6669**	**0.6287**	*0.3604*	*0.2092*	**0.7488**	**0.2214**
EC1	**2.4554**	**0.5597**	**2.4218**	**0.5521**	*0.0612*	*0.031*	**0.0671**	**0.0317**
EC2	**0.1938**	**0.0766**	**0.229**	**0.0878**	*0*	*0.0346*	*0*	*0.0347*
EC3	*0*	*0.0115*	*0*	*0.0115*	*0*	*0.0115*	*0*	*0.0115*
Total EC	**0.9005**	**0.178**	**1.0699**	**0.2097**	*0.0213*	*0.0441*	**0.0671**	**0.0458**
Total Carbon	**7.3173**	**0.7064**	**7.7368**	**0.7414**	*0.4047*	*0.2285*	**0.8159**	**0.2419**
Carbonate Carbon (CO_3^{2-})	*0.0626*	*0.2156*	*0*	*0.2149*	*0.023*	*0.2149*	*0*	*0.215*
Sodium, Na	*0.2117*	*0.0836*	*0.0776*	*0.0815*	*0.0606*	*0.0812*	*0.089*	*0.0817*
Magnesium, Mg	*0.1159*	*0.0436*	*0.023*	*0.0431*	*0.0435*	*0.0432*	*0.0102*	*0.043*
Aluminum, Al	**0.2366**	**0.0094**	**0.0868**	**0.0077**	**0.106**	**0.0079**	**0.0468**	**0.0074**
Silicon, Si	**0.5984**	**0.0159**	**0.199**	**0.0095**	**0.2826**	**0.0106**	**0.1067**	**0.0086**
Phosphorous, P	**0.0155**	**0.003**	**0.0139**	**0.003**	**0.0164**	**0.003**	**0.0168**	**0.003**
Sulfur, S	**0.2177**	**0.0133**	**0.2276**	**0.0134**	**0.3791**	**0.0151**	**0.3647**	**0.0149**
Chlorine, Cl	*0.016*	*0.0016*	*0.0085*	*0.0016*	*0*	*0.0016*	*0*	*0.0016*
Potassium, K	**0.3681**	**0.0077**	**0.2867**	**0.0061**	**0.0629**	**0.002**	**0.027**	**0.0016**
Calcium, Ca	**0.3514**	**0.0074**	**0.0939**	**0.0027**	**0.1341**	**0.0033**	**0.0421**	**0.0021**
Scandium, Sc	*0*	*0.0058*	*0*	*0.0058*	*0*	*0.0058*	*0*	*0.0058*
Titanium, Ti	**0.0219**	**0.0012**	**0.0076**	**0.0011**	**0.0106**	**0.0011**	**0.0038**	**0.0011**
Vanadium, V	*0.0007*	*0.0001*	*0*	*0.0001*	*0.0004*	*0.0001*	*0*	*0.0001*
Chromium, Cr	*0*	*0.001*	*0*	*0.001*	*0*	*0.001*	*0*	*0.001*
Manganese, Mn	*0.0075*	*0.0021*	*0.0023*	*0.0021*	*0.0022*	*0.0021*	*0.0002*	*0.0021*
Iron, Fe	**0.2008**	**0.0051**	**0.0443**	**0.0031**	**0.0614**	**0.0033**	**0**	**0.0029**
Cobalt, Co	*0*	*0.0001*	*0*	*0.0001*	*0*	*0.0001*	*0*	*0.0001*
Nickel, Ni	*0*	*0.0006*	*0*	*0.0006*	*0*	*0.0006*	*0*	*0.0006*
Copper, Cu	*0.0022*	*0.0009*	*0.0014*	*0.0009*	*0.0011*	*0.0009*	*0.0008*	*0.0009*
Zinc, Zn	**0.0061**	**0.0009**	**0.0053**	**0.0009**	*0.0004*	*0.0009*	*0.0026*	*0.0009*
Gallium, Ga	*0.0017*	*0.0031*	*0*	*0.0031*	*0.0008*	*0.0031*	*0.0014*	*0.0031*
Arsenic, As	*0*	*0.0001*	*0*	*0.0001*	*0*	*0.0001*	*0*	*0.0001*
Selenium, Se	*0*	*0.0021*	*0.0011*	*0.0021*	*0.001*	*0.0021*	*0*	*0.0021*
Bromine, Br	*0.0021*	*0.0015*	*0.0057*	*0.0015*	*0.0035*	*0.0015*	*0.0024*	*0.0015*
Rubidium, Rh	*0.0004*	*0.0011*	*0.0006*	*0.0011*	*0*	*0.0011*	*0*	*0.0011*
Strontium, Sr	*0.0031*	*0.002*	*0.0003*	*0.002*	*0*	*0.002*	*0*	*0.002*
Yttrium, Y	*0.0008*	*0.0015*	*0.001*	*0.0015*	*0*	*0.0015*	*0.0003*	*0.0015*

Table 3. Results of the chemical analysis for selected filters from Tonopah Airport. Chemical components with concentration higher than two times the uncertainty are in bold, while those with concentrations lower than two times the uncertainty are in italics. Concentrations are in μg/m^3 (continued).

DATE	10/27/2007				11/08/2007			
SIZE	PM_{10}		$PM_{2.5}$		PM_{10}		$PM_{2.5}$	
	Conc.	Uncer.	Conc.	Uncer.	Conc.	Uncer.	Conc.	Uncer.
Zirconium, Zr	*0*	*0.0034*	*0.0009*	*0.0034*	*0*	*0.0034*	*0*	*0.0034*
Niobium, Nb	*0*	*0.0026*	*0*	*0.0026*	*0.0018*	*0.0026*	*0*	*0.0026*
Molybdenum, Mo	*0*	*0.0024*	*0.0014*	*0.0024*	*0.0006*	*0.0024*	*0.001*	*0.0024*
Palladium, Pd	*0*	*0.0045*	*0*	*0.0045*	*0*	*0.0045*	*0*	*0.0045*
Silver, Ag	*0*	*0.0041*	*0*	*0.0041*	*0.0012*	*0.0041*	*0.0012*	*0.0041*
Cadmium, Cd	*0.0011*	*0.0052*	*0*	*0.0052*	*0.0035*	*0.0052*	*0*	*0.0052*
Indium, In	*0.0002*	*0.003*	*0.0013*	*0.003*	*0*	*0.0031*	*0*	*0.003*
Tin, Sn	*0.0012*	*0.0039*	*0.0026*	*0.0039*	*0*	*0.0039*	*0*	*0.0039*
Antimony, Sb	*0*	*0.0073*	*0*	*0.0073*	*0*	*0.0073*	*0*	*0.0073*
Cesium, Cs	*0*	*0.0012*	*0*	*0.0012*	*0*	*0.0012*	*0*	*0.0012*
Barium, Ba	*0*	*0.0006*	*0*	*0.0006*	*0*	*0.0006*	*0*	*0.0006*
Lanthanum, La	*0*	*0.0009*	*0*	*0.0009*	*0*	*0.0009*	*0.0005*	*0.0009*
Cerium, Ce	*0*	*0.0013*	*0*	*0.0013*	*0*	*0.0013*	*0*	*0.0013*
Samarium, Sa	*0.0008*	*0.0018*	*0.0008*	*0.0018*	*0*	*0.0018*	*0.001*	*0.0018*
Europium, Eu	*0*	*0.0064*	*0*	*0.0064*	*0*	*0.0064*	*0*	*0.0064*
Terbium, Tb	*0.0003*	*0.0024*	*0*	*0.0024*	*0*	*0.0024*	*0.0003*	*0.0024*
Hafnium, Hf	*0*	*0.0139*	*0.0016*	*0.0139*	*0*	*0.0139*	*0*	*0.0139*
Tantalum, Ta	*0*	*0.0117*	*0.0057*	*0.0117*	*0.0041*	*0.0117*	*0.0063*	*0.0117*
Tungsten, W	*0.0067*	*0.0168*	*0*	*0.0168*	*0*	*0.0168*	*0*	*0.0168*
Iridium, Ir	*0*	*0.0036*	*0*	*0.0036*	*0*	*0.0036*	*0*	*0.0036*
Gold, Au	*0.0031*	*0.0078*	*0*	*0.0078*	*0.0015*	*0.0078*	*0*	*0.0078*
Mercury, Hg	*0*	*0.0024*	*0*	*0.0024*	*0*	*0.0024*	*0*	*0.0024*
Thallium, Th	*0*	*0.0025*	*0*	*0.0025*	*0*	*0.0025*	*0*	*0.0025*
Lead, Pb	*0*	*0.0025*	*0.0005*	*0.0025*	*0.0026*	*0.0026*	*0*	*0.0025*
Uranium, U	*0*	*0.0041*	*0*	*0.0041*	*0.002*	*0.0041*	*0.0006*	*0.0041*

OC = organic carbon
EC = elemental carbon
OP = optical pyrolysis
TT = transmittance

With respect to the chemical composition of PM_{10} and $PM_{2.5}$, the following patterns are observed:

- Sulfur (S) was mostly in the form of sulfate (SO_4^{2-}) with sulfate-to-sulfur ratio of 2.86 to 3.85. Sulfate and ammonium were almost entirely (100% for sulfate, 100% for ammonium) associated with fine particles, while 9 to 60 percent of nitrate was measured in $PM_{2.5}$. Ammonium-to-sulfate molar ratios varied from 1.94 to 2.81, suggesting that sulfate aerosols were mostly in the form of ammonium bisulfate, $(NH_4)HSO_4$ (Malm *et al.,* 2002). Nitrates appeared to be partially neutralized by ammonium in the fine particle mode, while coarse particles nitrates may be the product of the reactions of nitric acid with soil dust elements such as Ca (Lefer and Talbot, 2001).

- Carbonaceous aerosol was predominantly in fine particles. For $PM_{2.5}$, total carbon (OC) concentrations accounted for 26 to 49 percent of particle mass, while very low EC/OC ratios were indicative of the absence of combustion-related sources
- Soluble potassium (K^+) accounted for 32 to 70 percent of total potassium in PM_{10} and for more than 50 percent of total potassium in $PM_{2.5}$. Soluble potassium is a tracer of biomass burning, which suggested the significant impact of emissions from local and/or regional fire (prescribed or wildfire) events or salts in desert soils. This was further supported by the estimates of nonsoil potassium $K_{non\text{-}soil}$ (K_{total}-(0.26 x [Al])) that were comparable to measured water-soluble K^+.
- Ratios of Al/Si (0.38 to 0.44) K/Fe (1.83 to6.47) were comparable to those determined for samples collected at the Interagency Monitoring of Protected Visibility Environments (IMPROVE) sites in western United States (Al/Si: 0.31 to 0.43, K/Fe: 0.67 to 0.78, Al/Ca: 1.4 to 1.7) when soil dust was the major component of particulate matter (Kavouras *et al.*, 2005).

The IMPROVE mass estimation scheme is adopted to reconstruct aerosol mass into five major types: sulfate, nitrate, organic, light-absorbing carbon, and soil. For this scheme, sulfate and nitrate are assumed to be in the forms of ammonium sulfate [$(NH_4)_2SO_4$] and ammonium nitrate [NH_4NO_3], respectively (Malm *et al.*, 2004). Organic mass concentration [OMC] was estimated as [OMC] =1.4 x [OC], where [OC] is the organic carbon concentration. The 1.4 factor was used to estimate for other elements (mainly hydrogen and oxygen) associated with the composition of organic compounds (White and Roberts, 1977). Soil mass concentration [SOIL] was estimated as the sum of the elements present in the soil as oxides (Al_2O_3, SiO_2, CaO, K_2O, FeO, Fe_2O_3, and TiO_2) as follows:

[SOIL] = 2.2 x [Al] + 2.49 [Si] + 1.63 x [Ca] + 2.42 x [Fe] + 1.94 x [Ti]. Therefore, the reconstructed aerosol mass was estimated as follows:

$$[\text{Aerosol Mass}] = (128/96) \times [SO_4] + (80/62) \times [NO_3] + EC + [OMC] + [SOIL]$$

Figure 6 shows the concentrations of ammonium sulfate, ammonium nitrate, organic carbon mass, elemental carbon, and soil for PM_{10} and $PM_{2.5}$ collected on October 27, 2007 and November 8, 2007 at the Tonopah Airport. Considering the positive bias for organic carbon measurements:

- Reconstructed particle mass accounted for 73 to 75 percent of measured PM_{10} mass and for 80 to 98 percent of $PM_{2.5}$ mass.
- Carbonaceous aerosol (OMC and EC) appeared to account for 11 to 50 percent of PM_{10} and 36 to 66 percent of $PM_{2.5}$.
- Soil represented 16 to 28 percent of PM_{10} and about 6 to 14 percent of $PM_{2.5}$ mass, while sulfate contributed between 6 and 30 percent on PM_{10} and 6 to 47 percent on $PM_{2.5}$ (Figure 6).
- The differences of PM_{10} and $PM_{2.5}$ fractions are due to higher concentration of soil elements in the coarse fraction (particles with diameter between 2.5 and 10 μm). Higher $PM_{2.5}$ mass concentrations for October 27, 2007, may be attributed to increased concentrations of organic carbon associated with smoke from wildfires in southern California (San Diego area).

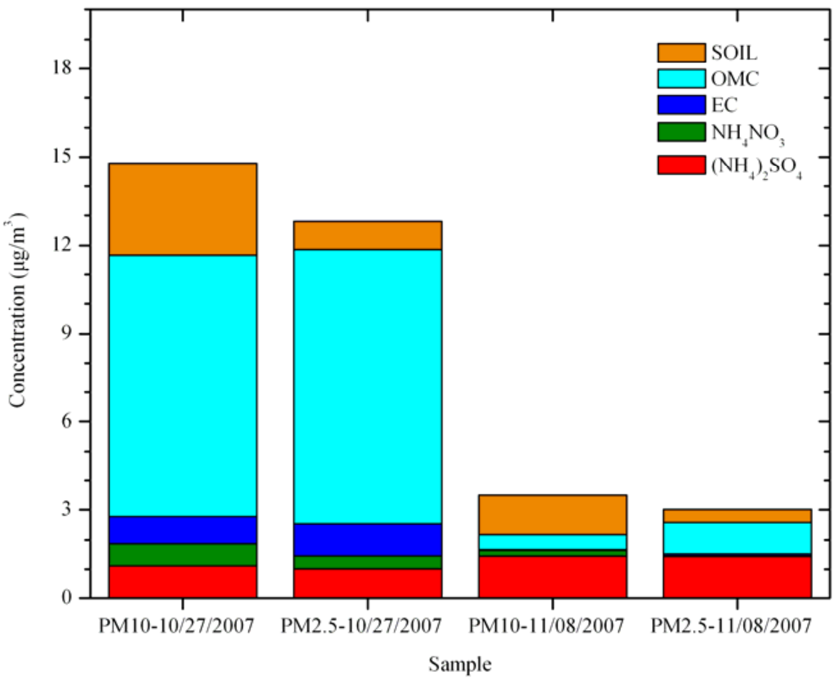

Figure 6. Reconstructed mass for PM_{10} and $PM_{2.5}$ based on chemical composition.

Aerosol Monitoring

Monitor Description and Procedures

The TEOM Series 1400 Ambient Particulate Monitor from Thermo Scientific and the DUSTTRAK™ Aerosol Monitor from TSI were used to continuously measure PM_{10} and $PM_{2.5}$ mass concentrations (Figure 7). The TEOM Series 1400 monitors the ambient particulate mass concentration of PM_{10} (EPA certification EQPM-1090-079) (or $PM_{2.5}$) in real time by direct measurement of particulate mass collected on a filter attached to an oscillating inertial mass transducer. The mass transducer in the sensor unit has a tapered ceramic tube (element) that is fixed at the downstream end and a Teflon-coated glass fiber filter on the free end. The oscillating frequency of the tube changes proportionally as ambient air is drawn through the filter and the particulate loading thereon increases. The flow rate through the filter sample is set at a nominal 3.0 liters/min. A bypass (auxiliary) flow provides an additional 13.67 liters/min for a total flow rate of 16.67 liters/min. An internal datalogger stores mass values, time, and some meteorological data. To eliminate bias caused by humidity, the filter is heated to 50°C. Operation, calibration, and maintenance of the TEOM are described in SOP DRI 4.111-2 “RUPPRECHT & PATASHNICK (R&P), SERIES 1400A TAPERED ELEMENT OSCILLATING MICROBALANCE (TEOM).” Flow calibration and leak tests were performed on the day of installation (September 27, 2007). Data were downloaded during site visits. Regular checks of time, filter loading, by-pass filter, and flow rates were accomplished during site visits.

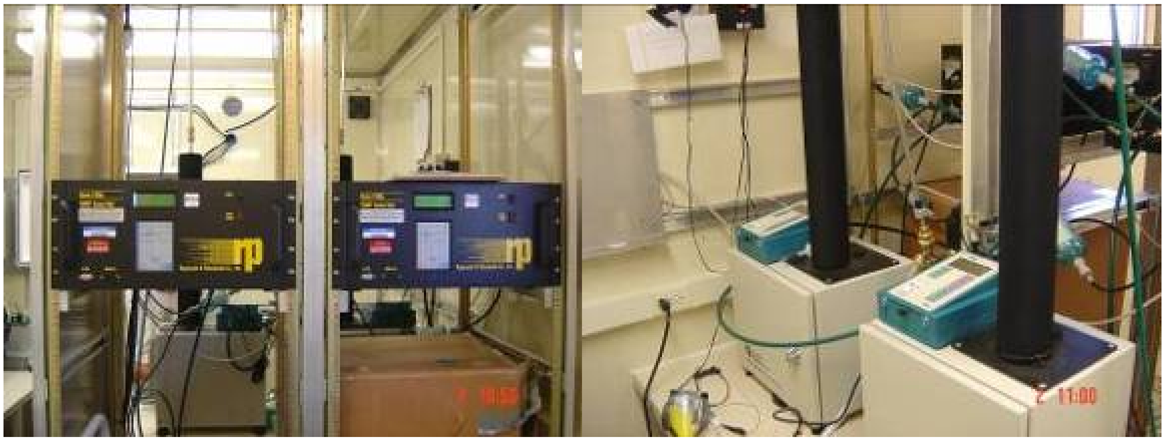

Figure 7. Left photograph: The front panels of PM_{10} (right on the left photograph) and $PM_{2.5}$ (left on the left photograph) of TEOM. Right photograph: The DustTrak monitors (green) resting on top of the two TEOM measuring units.

The DUSTTRAK™ Aerosol Monitors are portable, battery operated laser photometers that provide measurements of particle mass based on 90^o light scattering. Atmospheric aerosol passes through a size selective inlet (either PM_{10} or $PM_{2.5}$) and is directed to an optics chamber at a flow rate of 1.7 liters/min. The light source is a laser diode that emits light at a wavelength of 780 nm. The aerosol sample is drawn into the sensing chamber where it is illuminated with a narrow beam of laser light. Light scattered by aerosol particles is collected by a set of lenses and focused onto the photodetector. The detector signal is proportional to the amount of scattered light, which is proportional to the mass concentration of the aerosol. Voltage is read by the processor and multiplied by an internal calibration constant to yield mass concentration. The calibration constant is pre-set by the manufacturer for scattering characteristics of the respirable mass of ISO 12103-1, Al test dust. Local variations in aerosol particle size distribution and composition relative to this standard may result in differences in the actual response factor of the instrument. The operation, calibration, and maintenance of the DUSTTRAK are described in SOP DRI 2.112-2 "TSI INCORPORATED MODEL 8520 DUSTTRAK AEROSOL MONITOR FOR THE YUCCA MOUNTAIN AIR QUALITY PROGRAM."

Both PM_{10} and $PM_{2.5}$ DUSTTRAK inlets were attached on a wide "Y" connector, which was connected to one end of a second "Y" (Figure 8). A funnel was connected to the other end of the second "Y" to achieve fast exchange of ambient air into the sampling line. Flow calibration and zero-test were performed on the day of installation (August 29, 2007) and subsequent site visits. Deviations in flow were predominantly due to failure of the pump diaphragm. In those cases, the instrument was replaced. Deviations of the zero check were corrected by performing zero calibration according to the manufacturer's operational instruction manual.

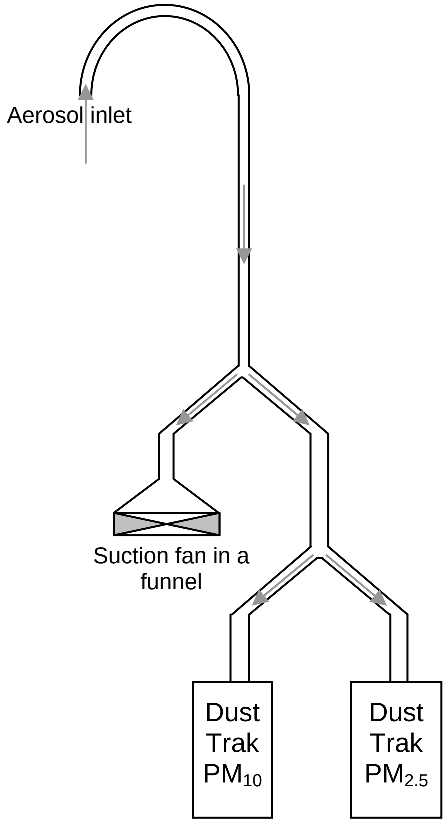

Figure 8. Schematic drawing of the sampling inlet for DUSTTRAK (not to scale).

Continuous Measurements of PM_{10} and $PM_{2.5}$

Trends and correlations of particle mass are examined using hourly TEOM data integrated for 24 hours (from 0:00. to 23:00). Statistics of 24-h particle mass are presented in Table **Error! Reference source not found.**4.

Table 4. Statistics for 24-h PM_{10} and $PM_{2.5}$ TEOM mass concentrations.

	Mean	Median	Minimum	Maximum	Std. Deviation
PM_{10}	7.6	6.4	3.2	33.1	4.8
$PM_{2.5}$	1.7	1.0	0.0	15.3	2.1

Twenty-four-h PM_{10} levels ranged from 3.2 to 33.1 $\mu g/m^3$, with a mean of 7.6 (σ=4.8) $\mu g/m^3$, while $PM_{2.5}$ concentrations varied from 0.0 to 15.3 $\mu g/m^3$, with a mean of 1.7 (σ=2.1) $\mu g/m^3$. Similar temporal trends were found for PM_{10} and $PM_{2.5}$ at Tonopah Airport. A high PM_{10} episode on October 26 through 28, 2007, was observed, with $PM_{2.5}$ mass concentration of approximately 9 $\mu g/m^3$ (Figure 9). Fine particles accounted for only 20 percent of PM_{10} mass ($PM_{2.5}/PM_{10}$ ratio of 0.20) (Figure 10). While differences in particle mass for weekdays/weekends were not statistically significant, somewhat higher PM_{10} levels were measured on Saturday (Day #6) (Figure 11).

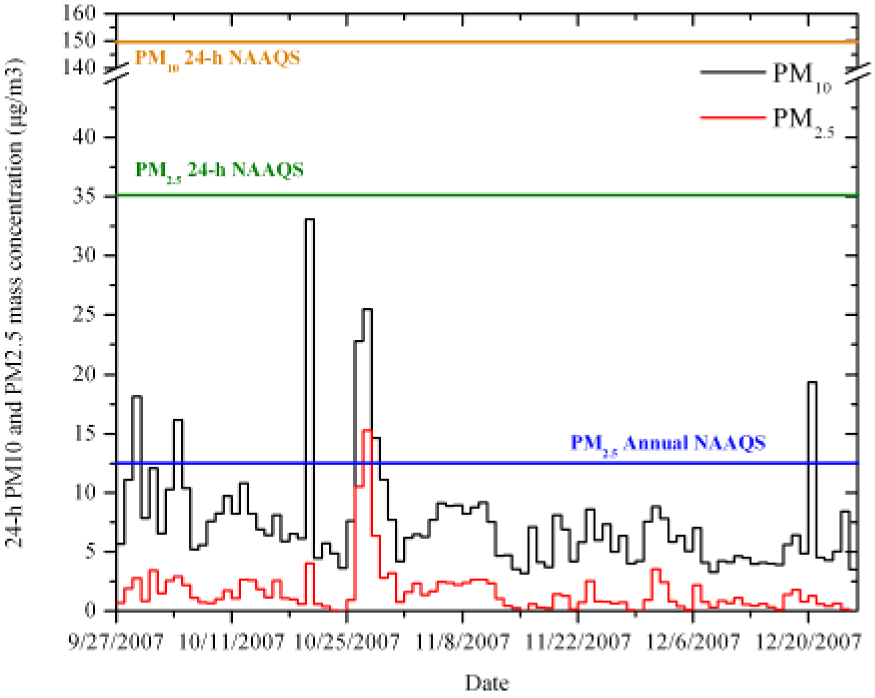

Figure 9. Mean 24-h PM_{10} and $PM_{2.5}$ mass concentrations measured by TEOM at Site #8 (Tonopah Airport).

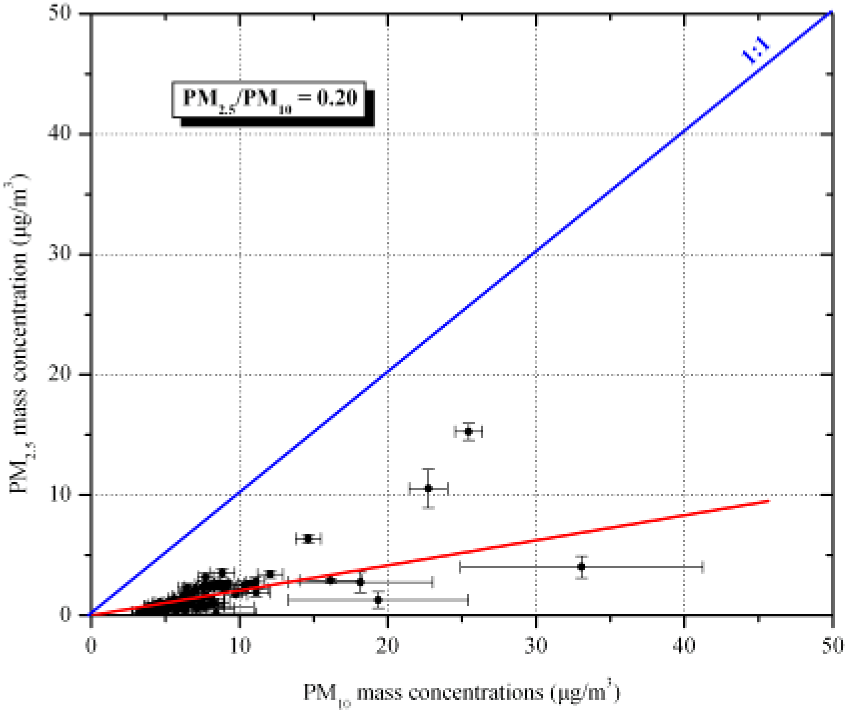

Figure 10. $PM_{2.5}/PM_{10}$ mass ratios measured by TEOM at Site #8 (Tonopah Airport). Error bars represent the standard error of the mean.

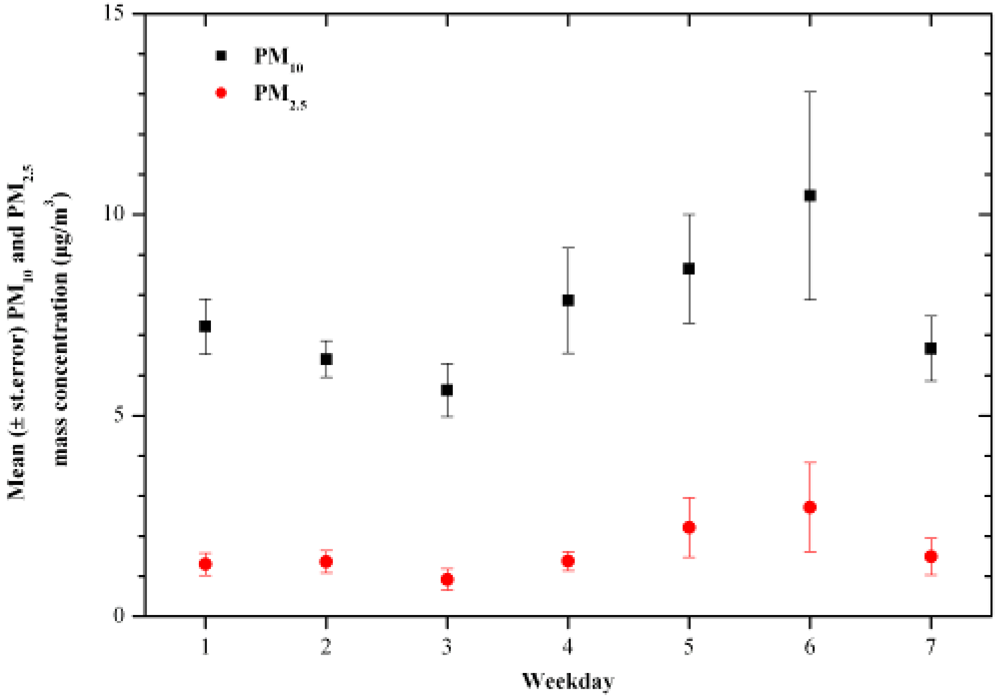

Figure 11. Variation of mean (± st.error) PM_{10} and $PM_{2.5}$ (µg/m^3) in weekdays and weekends at Site #8 (Tonopah Airport) (Monday=1, Tuesday=2, Wednesday=3, Thursday=4, Friday=5, Saturday=6, Sunday=7).

Variations of daily PM_{10} and $PM_{2.5}$ measured with DUSTTRAK and TEOM are presented in Figure 12 and Figure 13. The absolute differences between concentrations measured by DUSTTRAK and TEOM were larger for PM_{10} as compared to those for $PM_{2.5}$. Daily trends of particle mass concentrations measured by DUSTTRAK and TEOM were comparable for $PM_{2.5}$ mass. The time series plots for PM_{10} particle mass concentrations measured by TEOM and DUSTTRAK are somewhat comparable in shape and almost identical for $PM_{2.5}$. The temporal correlations between DUSTTRAK and TEOM were low to moderate (R=0.32 to 0.70). A slope of 9.0980 and an intercept of -22.14122 µg/m^3 (Figure 14) were computed for PM_{10}. This was indicative of the weakness of the light-scattering technique to monitor dust particles that represented more than 80 percent of PM_{10} mass at the Tonopah Airport at very low concentration levels. As for $PM_{2.5}$, the slope between TEOM and DUSTTRAK $PM_{2.5}$ was 2.54327, with a rather low intercept of -0.9549 µg/m^3. This agreement was due to the fact that light scattering provides more reliable measurements of particle mass in the accumulation mode.

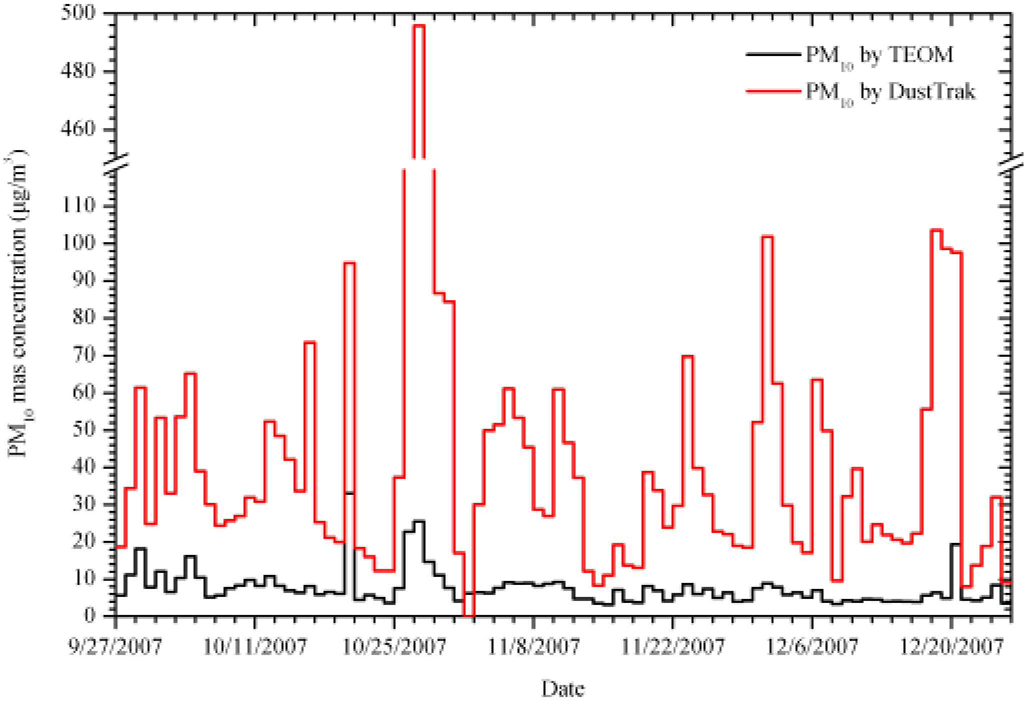

Figure 12. PM_{10} mass (µg/m^3) measured with DUSTTRAK and TEOM at Site #8 (Tonopah Airport).

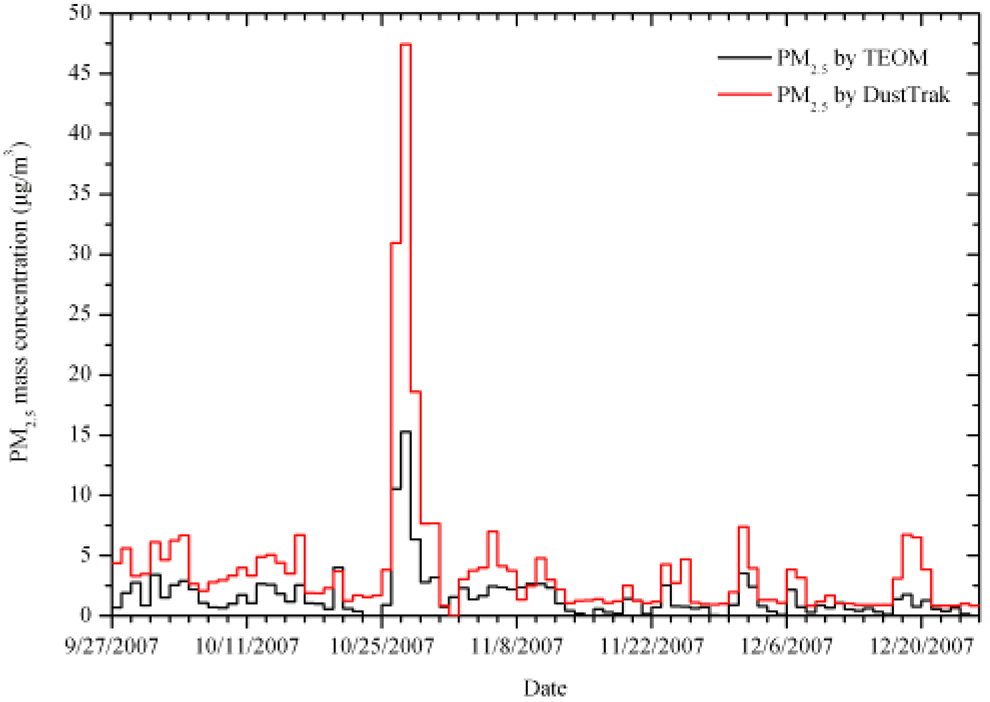

Figure 13. $PM_{2.5}$ mass (µg/m^3) measured with DUSTTRAK and TEOM at Site #8 (Tonopah Airport).

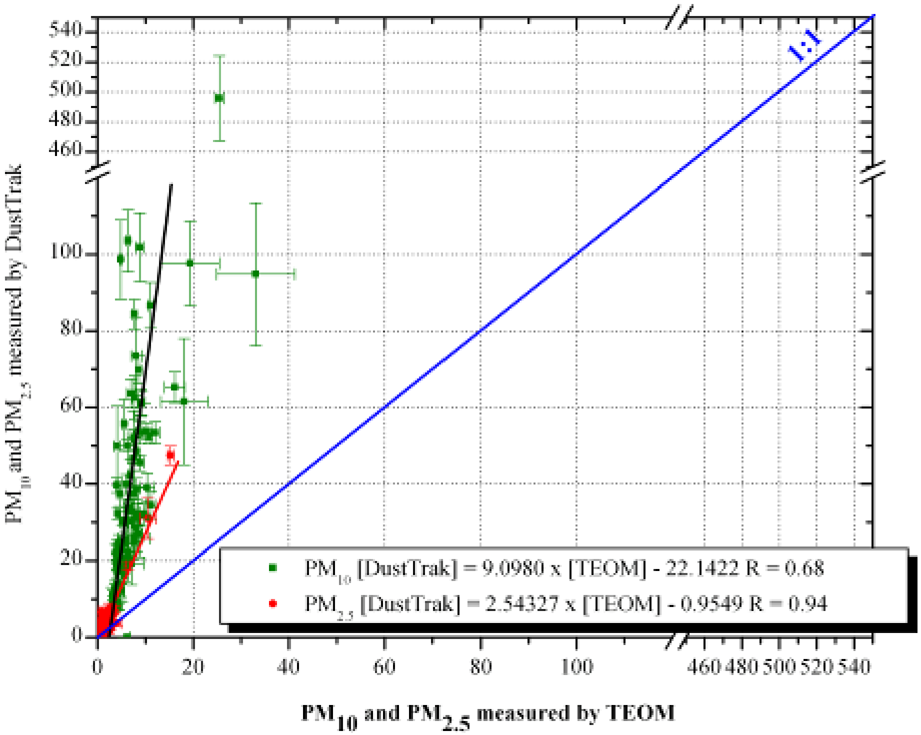

Figure 14. Comparison of 24-h PM$_{10}$ and PM$_{2.5}$ mass concentrations measured by TEOM and DUSTTRAK. Error bars represent the standard error of the mean.

Comparison of Filter to Continuous Results

Figure 15 and Figure 16 show the relationships between PM$_{10}$ and PM$_{2.5}$ measured by TEOM/DUSTTRAK and FRM filter-based methods. The temporal correlations between PM$_{10}$ and PM$_{2.5}$ measurements by TEOM and filter methods were good, with correlation coefficients from 0.94 to 0.97. The slopes for PM$_{10}$ and PM$_{2.5}$ measured by TEOM and filters were 1.0533 and 0.93851, respectively, with intercepts of 3.22741 and -0.22317. The agreement between DUSTTRAK and filter-based PM$_{10}$ and PM$_{2.5}$ measurements was quite poor (R=0.15 to 0.35), with a slope of 1.9957 for PM$_{10}$ and 0.25695 for PM$_{2.5}$, while high intercepts are computed.

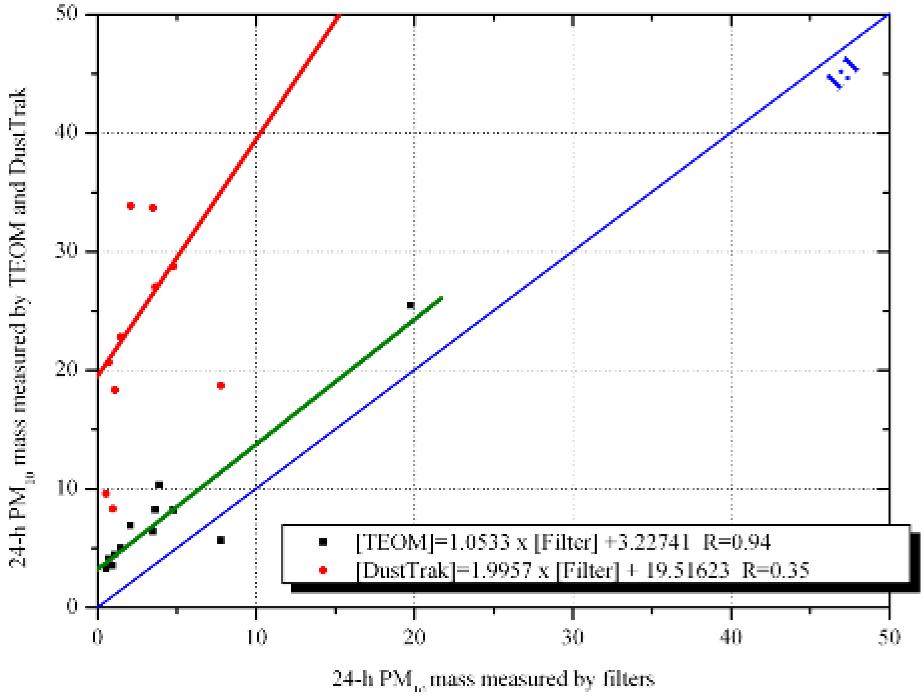

Figure 15. Relationships between PM_{10} concentrations (µg/m^3) measured by TEOM, DUSTTRAK, and filter-based methods.

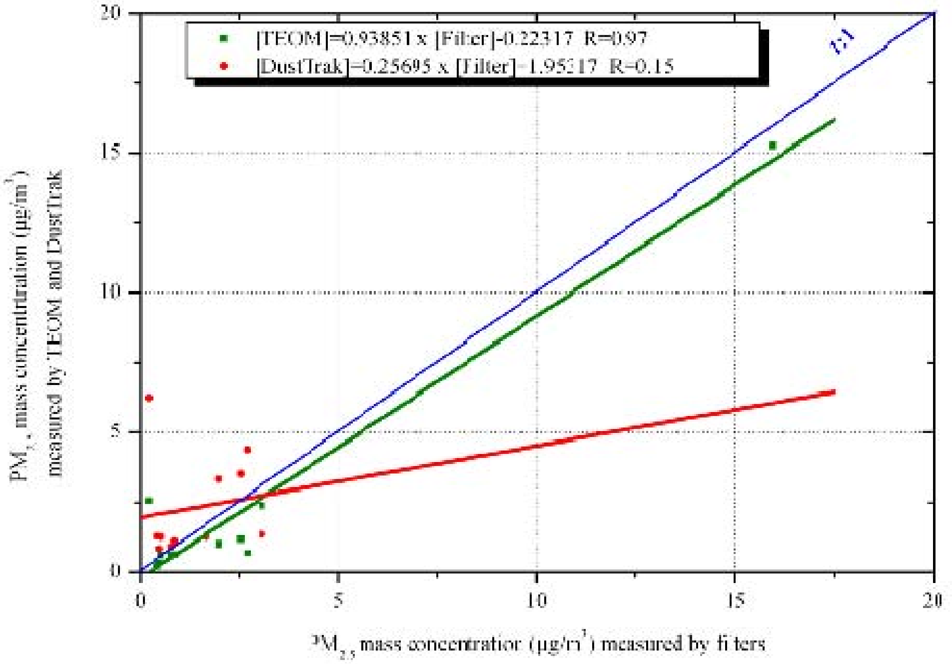

Figure 16. Relationships between $PM_{2.5}$ concentrations (µg/m^3) measured by TEOM, DUSTTRAK, and filter-based methods.

METEOROLOGY

Variations of hourly data for each meteorological parameter are presented in Figure 17 through Figure 21. Descriptive statistics of hourly data also are presented in Table 5. Solar radiation progressively increased up to 76.7 watts/m^2 (Figure 17). Ambient temperature varied from 11.3 to 93.3°F, with a mean temperature of 48.0°F for the monitoring period (Table 5; Figure 18). Four rainfall events adding up 2.06 mm were recorded (Figure 19).

Table 5. Descriptive statistics of 1-hour meteorological data.

	Mean	Minimum	Maximum	Sum
Solar radiation (watts/m^2)	14.5	0.0	76.7	
Wind speed (miles/h)	8.9	0.1	33.6	
Temperature (°F)	48.0	11.3	93.3	
Relative humidity (%)	40.2	4.0	97.5	
Precipitation (mm)				2.06

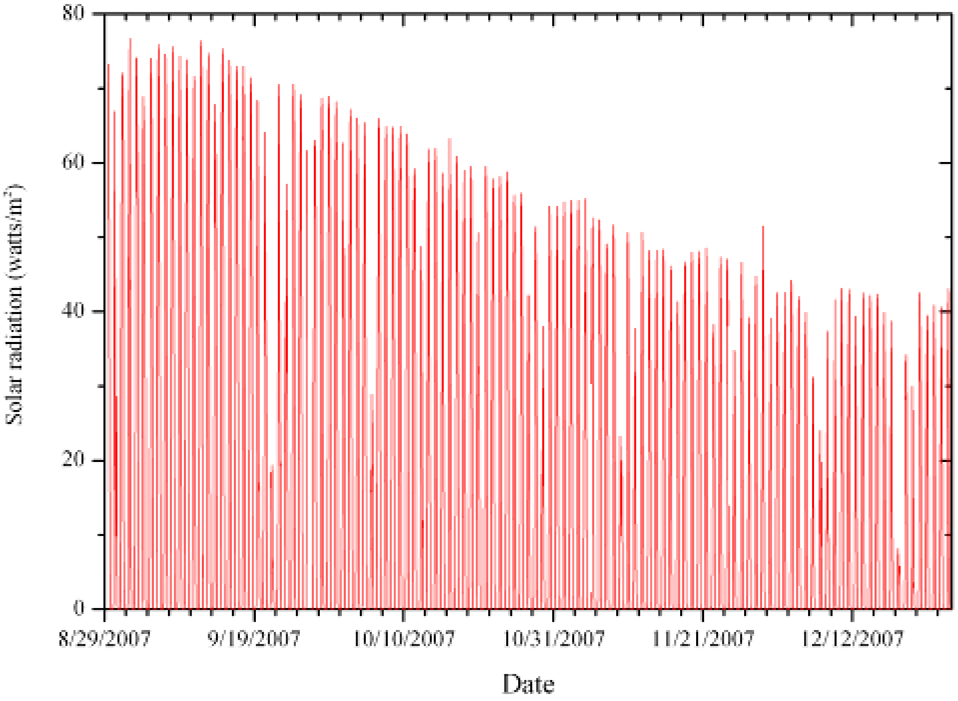

Figure 17. Solar radiation (in watts/m^2) at Site #8 (Tonopah Airport).

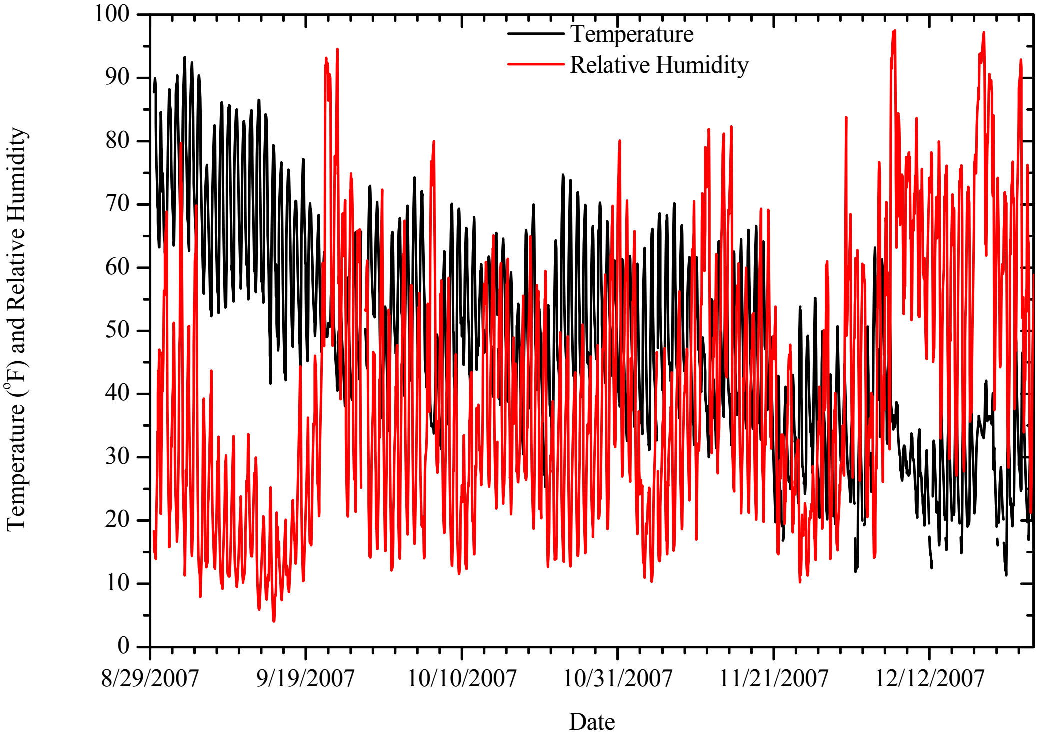

Figure 18. Temperature (in ºF) and relative humidity at Site #8 (Tonopah Airport).

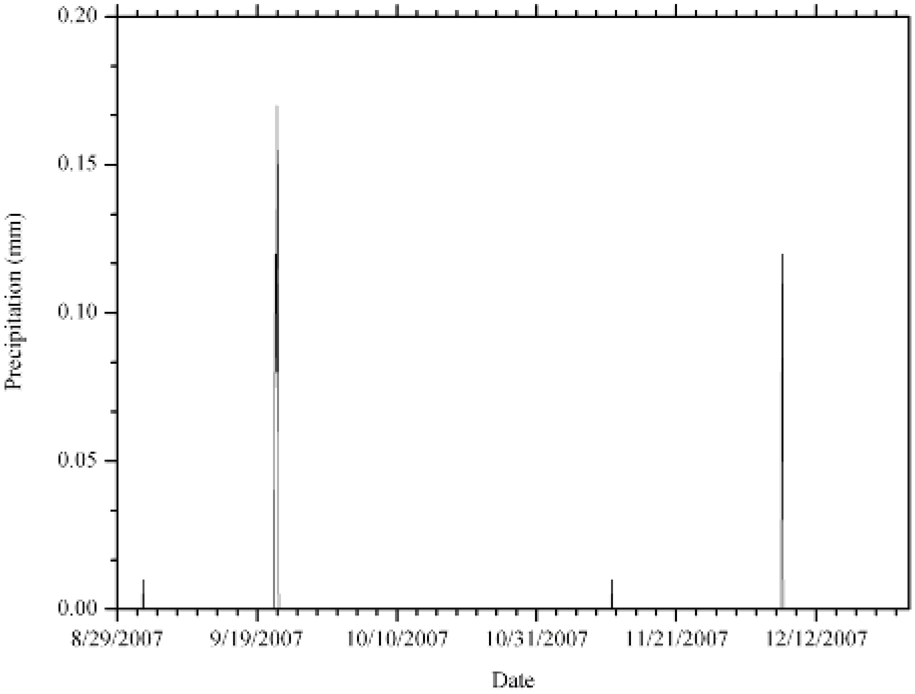

Figure 19. Total precipitation (in mm) at Site #8 (Tonopah Airport).

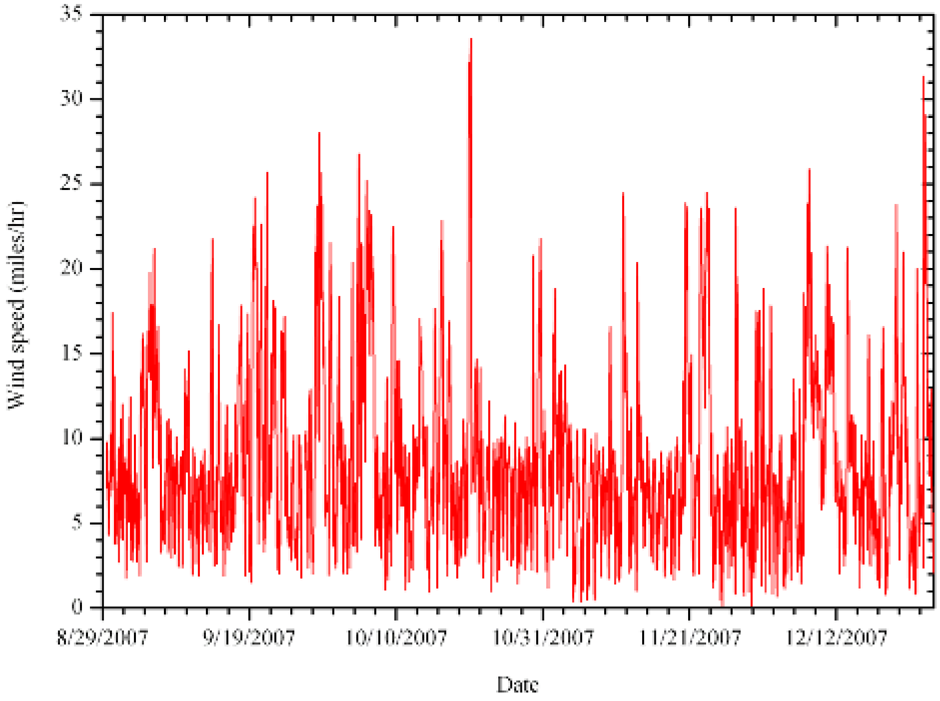

Figure 20. Wind speed (in miles/hr) at Site #8 (Tonopah Airport).

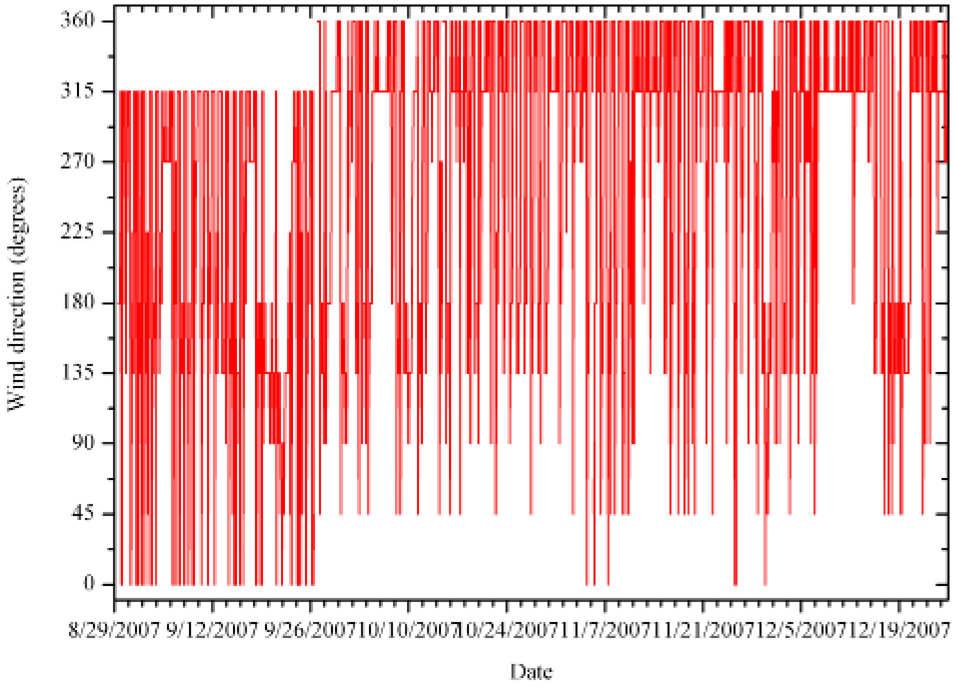

Figure 21. Wind direction at Site #8 (Tonopah Airport).

Wind conditions for the monitoring period were described by north/northwest winds during the night and southeast winds during the day, with wind speeds mostly in the range of 5 to 15 miles/hour (Figure 20 and Figure 21). The classification of wind conditions was retrieved from the Federal Meteorological Handbook (Table 6). The mean wind speed for each direction bin (8 bins) is presented in Figure 22.

Table 6. Wind condition classifications.

Miles/hour	Specification
<1	Calm; smoke rises vertically.
1 to 5	Direction of wind shown by smoke drift not by wind vanes. Wind felt on face; leaves rustle; vanes moved by wind.
5 to 9	Leaves and small twigs in constant motion; wind extends light flag.
9 to 14	Raises dust, loose paper; small branches moved.
14 to 23	Small trees in leaf begin to sway; crested wavelets form on inland waters. Large branches in motion; whistling heard in overhead wires; umbrellas used with difficulty.
23 to 35	Whole trees in motion; inconvenience felt walking against wind. Breaks twigs off trees; impedes progress.
35 to 48	Slight structural damage occurs. Trees uprooted; considerable damage occurs.
>48	Widespread damage.

(retrieved from Federal Meteorological Handbook; Chapter 5. Wind; ***http://www.nws.noaa.gov/oso/oso1/oso12/fmh1/fmh1ch5.htm#chp5link***)

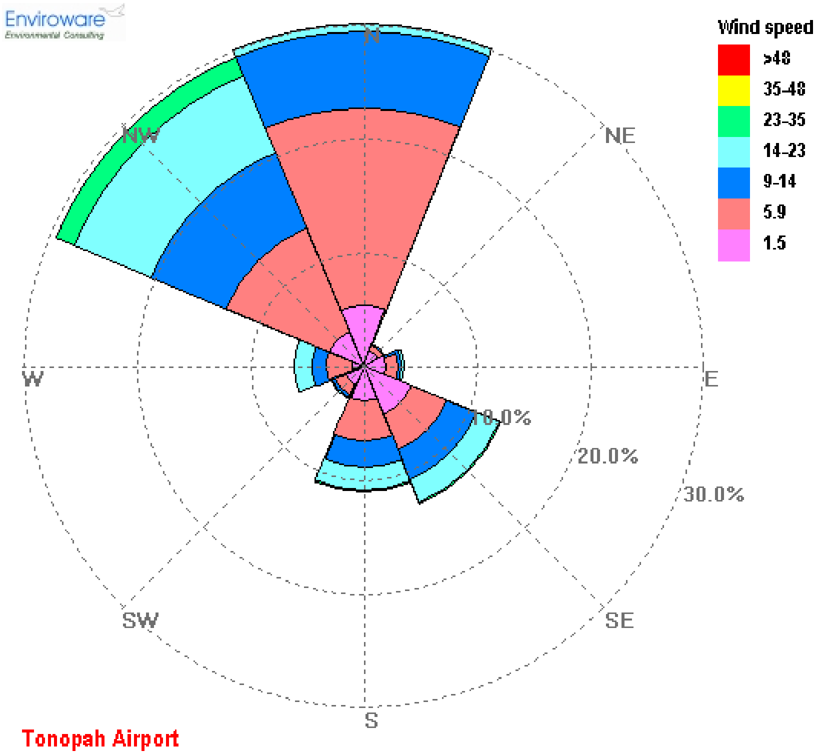

Figure 22. Wind direction and speed at Tonopah Airport.

For the entire monitoring period, winds were blowing from the north and northwest. Less than 3 percent of southeast winds were associated with wind speeds higher than 14 miles/hour, with a mean wind speed of 8.9 miles/hour. This is partly controlled by the topography of the region. Lower wind speeds are recorded for winds blowing from the northeast (mean wind speed of 3 miles/hour) (Figure 23).

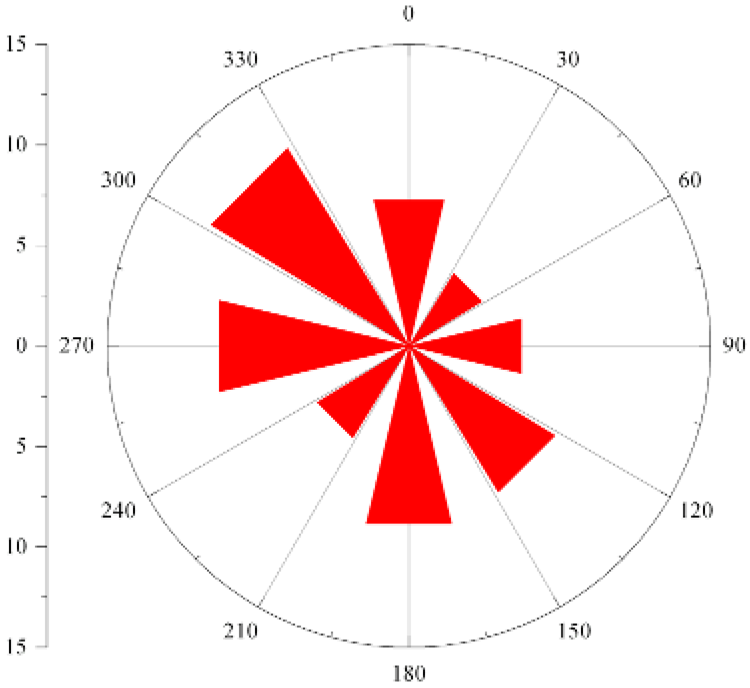

Figure 23. Average wind speed for each wind direction sector. Error bars represent the standard error of the mean.

Relationships of Meteorology with Aerosol Measurements

Trends and correlations of PM mass with meteorological conditions are shown for hourly TEOM data. The increase in wind speed triggered higher PM_{10} concentrations but a gradual decrease on $PM_{2.5}$ concentrations. A rather bimodal pattern is observed for both fractions of particle mass (Figure 24). The first mode is associated with comparatively higher particle mass concentration in early morning (5:00 to 6:00) followed by a gradual decrease. A second, less pronounced mode can be observed in late afternoon (18:00 to 20:00), especially for the fine fraction. There are no significant differences of $PM_{2.5}$ concentrations for different wind directions, while somewhat higher PM_{10} levels were recorded for southerly winds as compared to those blowing from the north (Figure 25 and Figure 26).

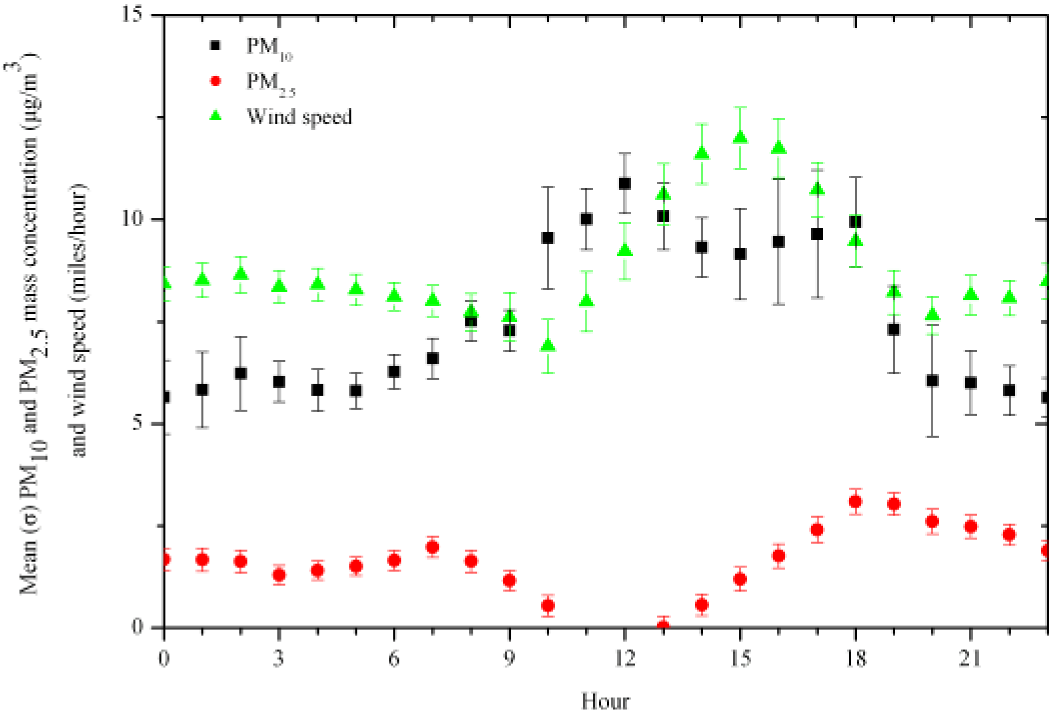

Figure 24. Hourly variation of PM_{10} and $PM_{2.5}$ mass concentrations (µg/m^3) as well as wind speed (miles/hour) at Site #8 (Tonopah Airport). Error bars represent the standard error of the mean.

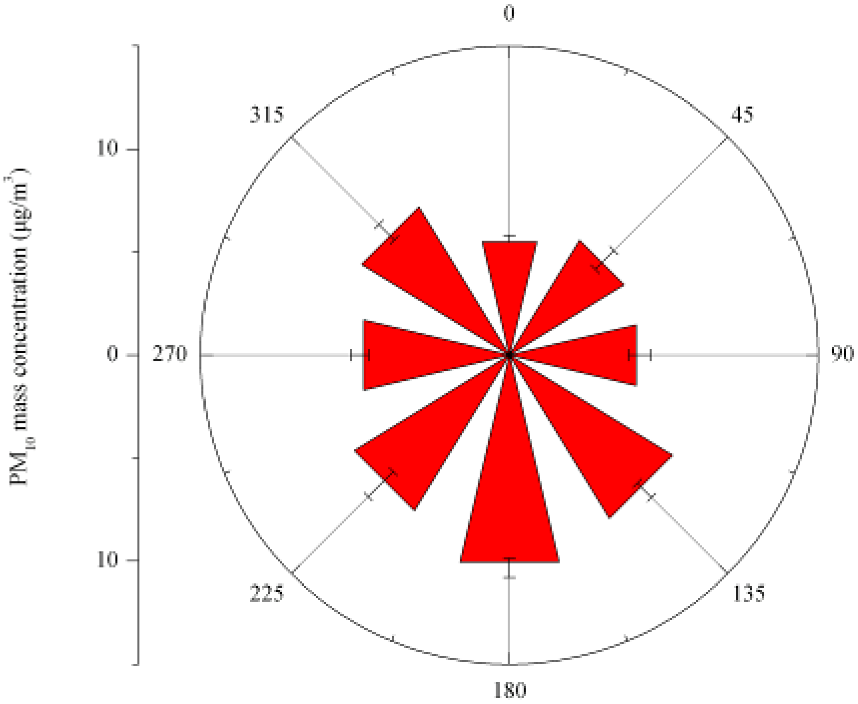

Figure 25. Mean (± st.error) of PM_{10} mass concentrations (µg/m^3) for different wind direction sectors at Site #8 (Tonopah Airport).

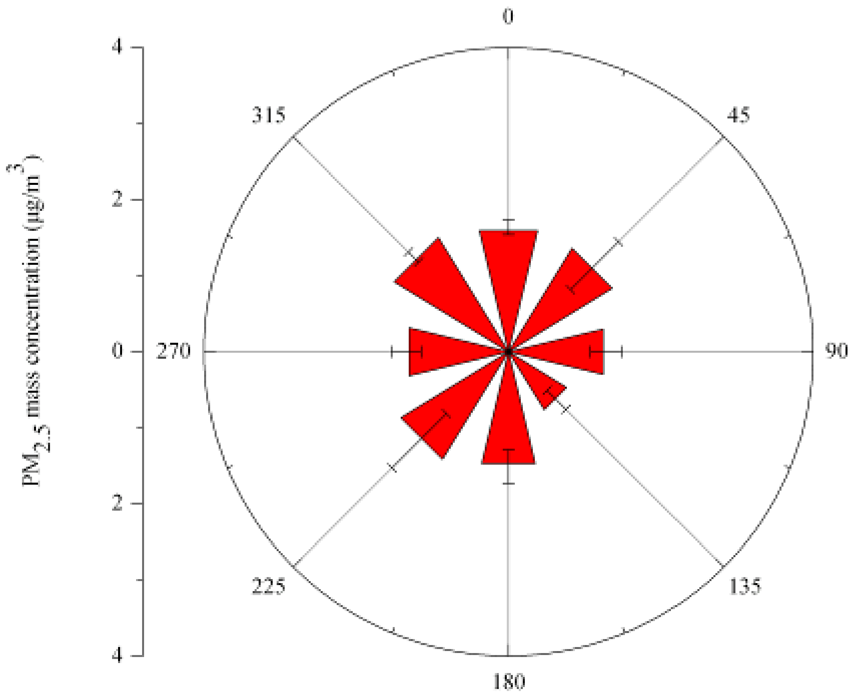

Figure 26. Mean (± st.error) of $PM_{2.5}$ mass concentrations (µg/m^3) for different wind direction sectors at Site #8 (Tonopah Airport).

CONCLUSIONS

PM_{10} and $PM_{2.5}$ mass concentrations and meteorological conditions were monitored at the Tonopah Airport from August 29 to December 19, 2007. Integrated samples of PM_{10} and $PM_{2.5}$ were collected using FRM samplers on a 1-to-6-day schedule. Two sets of filters (October 10 and November 8, 2007) were analyzed for major anions (sulfate, nitrate, chloride) and cations (sodium and potassium), elements (from sodium to uranium), and elemental and organic carbon. The comparison of PM_{10} and $PM_{2.5}$ mass concentrations obtained by continuous monitors and filters showed that differences are associated with the limitations of the instrumentation.

Mean 24-h concentrations of PM_{10} and $PM_{2.5}$ mass were 7.6 and 1.7 µg/m^3, which are significantly lower than the 24-h and annual NAAQS standards (24-h PM_{10}: 150 µg/m^3, 24-h $PM_{2.5}$: 35 µg/m^3; Annual $PM_{2.5}$: 15 µg/m^3). Higher PM_{10} mass concentrations were recorded during the day. Comparatively lower $PM_{2.5}$ levels were associated with increased wind speeds blowing mostly from the north/northwest in the early afternoon. The chemical composition of both PM_{10} and $PM_{2.5}$ samples indicated that organic carbon is the major component of both fractions, while soil contributes approximately 15 to 30 percent of PM_{10} mass. Sulfate and nitrate account for about 10 percent. Increases in PM_{10} and $PM_{2.5}$ mass concentrations were due to higher contributions from organic mass.

ACKNOWLEDGEMENTS

Authors thank the Nye County Department of Public Works and James L. Klapper for hosting the mobile trailer at the Tonopah Airport and providing assistance of the installation of electrical power.

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